Scientific Article

Accurately Determining the Density of Asphalt

By 2007 world asphalt production was estimated by the National Asphalt Pavement Association (NAPA) to be about 1.6 trillion metric tonnes with demand growing year on year [2]. More than 90% of the roads around the world are asphalt paved and the network continues to increase. NAPA estimates that the amount of investment in road infrastructure provided by the public sector alone across the US and Europe is more than $190 billion per year [3].

Why use Asphalt for Roads?

Asphalt is prepared from various combinations of stone, sand, and gravel, bound together by a mixture of bitumen and Portland cement, also known as asphalt cement. Asphalt pavement is engineered to handle the heaviest traffic, ranging from cars to aircraft [4]. The most common asphalt perpetual pavement can last indefinitely, provided that routine surface maintenance/replacement is carried out every 12 to 20 years. Asphalt is one of the most versatile materials for road paving with a range of specifications suitable for applications including airports, car parks, roads and racetracks. Even superstructures like dams are designed with an asphalt concrete core. Asphalt roads actually offer a superior driving surface to concrete paved highways.

Advantages of asphalt over concrete are:

- The surface is smoother compared to concrete, which means lower fuel consumption, quieter roads and much less overall cost
- Better road holding because of superior 'grip' compared to concrete
- Much quicker to construct than concrete with maintenance being swift, cost-effective and less disruptive
- Asphalt can be recycled/reactivated for use in new roads and ultimately less than 1% ends up in landfill [4]

Bitumen or asphalt is a black semi-solid viscous material traditionally used in waterproofing or as a mastic or glue, but now is principally used in road pavement construction. The global bitumen industry provides 85% of all bitumen mixed with aggregate filler for use in asphalt pavements. Only 10% is provided for roofing, waterproofing and sealing [1].

Density Testing: A Key Parameter for Asphalt

Asphalt density (weight of material per volume) is one of the most important measurements used for calculations to determine the quality and quantity of asphalt necessary to pave a particular road. In the calculation of the weight of material needed, a good awareness of the compacted density of the asphalt concrete is critical [5]. The quality and uniformity of an asphalt mixture controls whether a road will be paved consistently to attain the highest quality and most robust surface. ASTM D70-09 is the standard test method for accurately measuring and matching the density of semi-solid bituminous materials or asphalt with the project requirements. This analytical method is a pycnometer method [6] and is the one recommended by ASTM international.

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Pycnometer Testing for Ashphalt

A pycnometer is a glass device used by analytical scientists to determine the density and volume of irregular shaped solids or semi-solid materials. The device is made of glass and consists of a two chamber glass bottle with a precision ground glass stopper equipped with a capillary tube to allow gas to escape. The sample is poured into the calibrated pycnometer, which is then weighed and the remaining volume is filled with water. The filled pycnometer is then ready for the next stage that requires heating or cooling to the test temperature (monitored by a thermometer) before final accurate weighing. The density of the sample may then be calculated from the pycnometer mass and the mass of the water displaced by the sample in the filled instrument.

Problems

The ASTM International Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method) - (ASTM D70-09) has some problems, which have to be addressed in the modern analytical laboratory where automated processes as well as electronically verified data are becoming the norm. Indeed one of the most salient problems is that the ASTM D70-09 technique is rather long and drawn-out, requiring much more preparation and man hours than more up-to-date analytical methods. Other issues include:

- Specialised analytical training is required and without careful attention this method can be prone to analyst error
- The pycnometer process requires repeated heating and cooling using a water bath
- Multiple measurements are required using an analytical balance. In addition, if the glass breaks during the measuring process, the whole test has to be repeated with a new clean glass pycnometer and so there could be significant variation
- The glass pycnometer method requires a much larger sample than more modern methods
- Glass pycnometers require significant cleaning after each measurement before reuse and contamination could be an issue

Customer Story ...

"We ran density by pycnometer using the Hubbard-Carmick vials for years on our coker feed samples. It first involved weighing a clean pyc., then carefully filling it with water to the very top. You then replace the cap, forcing water through the hole in the cap to ensure there's no air present. If there are bubbles, you have to refill the vial. You then weigh the vial with water, then dry it out.

The sample, often being too solid to pour, is heated. Once it's pourable (and generally extremely hot), it's very carefully poured into the vial to the half point. If you pour too much, it affects the accuracy of the test and the vial must be cleaned and the whole process restarted. The sample is allowed to cool, then the weight of the sample is taken.

Water is then added to the vial to the top, as before, and a final weight taken. The final value is a calculation of these four weights, which is then referenced to API tables for a result. The vial could then be cleaned (a tedious task unto itself) and reused later.

The entire process was extremely time-intensive and in a busy production lab it was an unwelcome task.

With the AccuPyc, we've been able to cut what was a 30 minute to an hour task into a few minutes of prep work: heat the sample, weigh the cup, pour the sample into the cup, allow to cool, then run. The results from the instrument have been consistent with those from the pyc and are likely more accurate, as it takes away a lot of the human error inherent with using a pycnometer.

We've had the instrument several years now, and I still have technicians thanking me for purchasing it!"

Lab Specialist at S&P 500 Chemical Company

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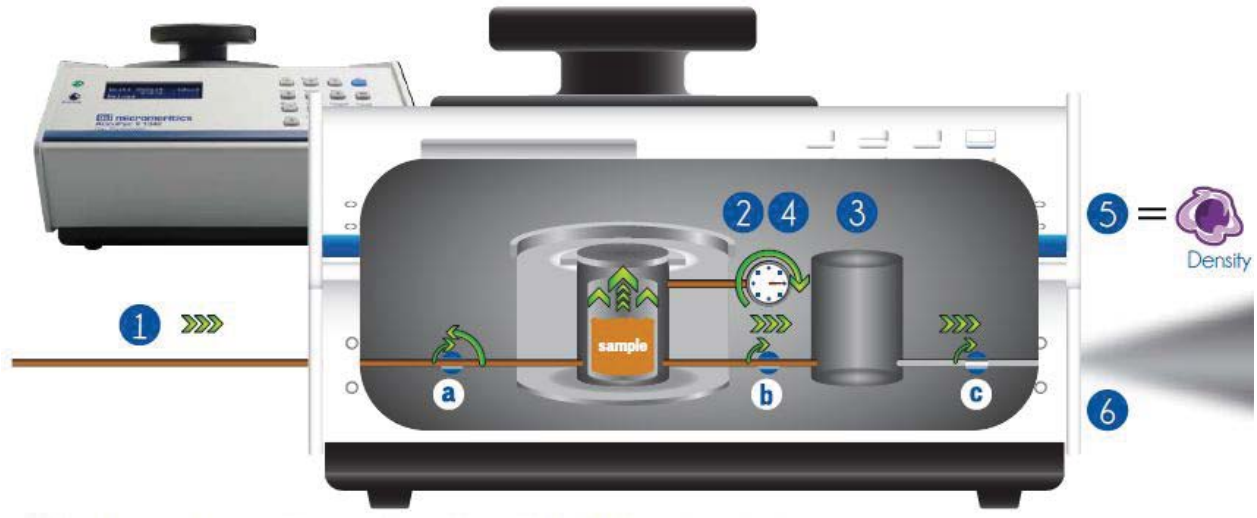
New Methodology

A modern analytical technique utilizes an automated pycnometer such as the AccuPyc II 1340 TEC, a fully automatic gas displacement pycnometer. This system can easily provide volume and density measurements able to meet the ASTM D70-09 method [7] [8]. The AccuPyc II 1340 TEC series provides an excellent solution with high-speed and precision volume measurements and also removing the potential for human error. By using inexpensive disposable sample cups, this is a much faster, cleaner, and easier technique. A final advantage for this method is that the sample volumes required for testing are markedly smaller than classical pycnometer technique.

The AccuPyc II 1340 TEC includes an integrated Peltier thermoelectric controller (TEC), which with its ability to provide temperature stability and accurate temperature control, makes it ideal for obtaining true or apparent volume and density of viscous materials such as asphalt at controlled temperatures. The PC-based control software of the AccuPyc II 1340 TEC provides an ideal way to calculate, record and verify asphalt density and volume while allowing data to be carefully correlated to results obtained with ASTM Test Method D70-09 if required.



1. Inert gas flows into a sample chamber - valve **a** opens then closes
2. Equilibrium is reached
3. Gas flows into second chamber for volume measurement - valve **b** opens
4. Equilibrium is reached yet again
5. Volume is divided into sample weight determines density
6. Pressure vented off to atmosphere - valve **c** opens

Conclusion

The AccuPyc II 1340 TEC is undoubtedly the ideal answer to providing rapid and accurate density calculations for semi-solid bituminous materials. Advantages of the instrument include disposable 3.3 cm3 sample cups to limit contamination and minimize cleaning of the sample chamber between analyses, and an integrated temperature control and data handling system. A recent study [7] compared ASTM D70-09 method with AccuPyc II TEC to measure the density of four asphalt samples. The results showed only a 0.003% to 0.026% difference between the two sets of results [7]. This result demonstrates the accuracy of the AccuPyc II TEC and provides good evidence for its ability to provide a much easier and rapid analytical method for the asphalt industry.

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